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Preliminary Results of

Red Pine Seed-Source Tests

In Northwestern Pennsylvania

by

A. F. Hough

Northeastern Forest Experiment Station

Ralph W. Marquis, Director

Upper Darby, Pa.

Forest Service, U.S. Dept. of Agriculture

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A. F. Hough, *silviculturist*

Northeastern Forest Experiment Station
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In the Lake States, in New England, and in the Middle Atlantic States thousands of acres of abandoned farm land and land denuded by ax and fire have been planted with red pine (Pinus resinosa Ait.).

Most of the seed used to grow the nursery stock for this reforestation work was collected in the Lake States. Here red pine is within its natural range. But many of the plantings took the species outside its natural range.

Out of this arose a question: How well is red pine seedling stock adapted to climatic and soil conditions of planting sites far distant from its seed source?

The Lake States Forest Experiment Station of the U.S. Forest Service started to study this question in 1928. One of the test plantations in this study was established at the Kane Experimental Forest in northwestern Pennsylvania. This is a report on the results of the first 10 years' tests at the Kane plantation.

NATURAL RANGE & IMPORTANCE OF RED PINE

Red pine has a botanical range from Nova Scotia and northern Ontario to southern Manitoba, southward to Minnesota, Wisconsin, central Michigan, New York, Massachusetts, Pennsylvania, and West Virginia.

In the eastern United States red pine is rarely found in dense, pure stands. It is usually represented by scattered trees mixed among eastern white pines. Like white pine, it is a long-lived subclimax species.

In Pennsylvania red pine is found naturally only in the northern and central parts of the State. It reaches down to Centre and northern Huntingdon Counties, extending eastward to the folded ridges of the Anthracite Region and westward to Clearfield, Cameron, and McKean Counties. In the Lake States extensive stands of red pine are found in the so-called "pineries" on sandy glacial till or old lake beds. There--except for some fairly extensive second-growth stands in northern Minnesota--logging and fire have reduced the original stands to remnants; and scattered individual trees must often serve as seed sources.

Red pine is a "pioneer" conifer. It is well adapted to fairly dry or infertile sites and is able to grow successfully in open land denuded of tree growth. Because of its rapid growth, good form, good survival, and relative freedom from natural enemies, the species has become a number-one choice for reforesting old burns and abandoned fields or pastures.

Rudolf (11)[1] reports that red pine ranked first (40 percent) among the tree species planted on 1.4 million acres of the Lake States in 1926-44. Stoeckeler and Limstrom (13) recommend red pine as one of the best species for reforestation on suitable sites in northern Wisconsin and upper Michigan. Hetzel (5) recommends it for northwestern Pennsylvania. The species has been used extensively in the tree-planting program of New York State (2).

[1] UNDERLINED NUMBERS IN PARENTHESES REFER TO LITERATURE CITED, PAGE 18.

Red pine has been brought considerably outside its botanical range in plantings. Plantings in southern New England, southeastern New York (8), New Jersey, southeastern Pennsylvania, Delaware, and Maryland are beset with difficulties unless climatically adapted strains are used. Red pine plantations in such southerly locations are preyed upon by insects such as the shoot moth and by various diseases (3, 4, 7).

Most of the red pine seed used in the United States for reforestation has its origin in the Lake States. Native stands of virgin and second-growth timber provide most of the seed. Some plantation-grown seed is collected, but here too the original source of the planted trees was very likely in the Lake States.

IMPORTANCE OF SEED SOURCE

Studies of seed from different geographic regions or climatic zones have shown that strains or races exist within many of the pines, spruces, firs, larches, beech, and other species that are under management in European forests. In some species the race can be identified by exterior or morphological characteristics and by rate of growth, frost hardiness, and heat resistance. In others there are no dendrological differences, since the inherited characteristics that make for racial variation are internal or physiological. In Europe the altitudinal boundaries and climatic distribution of tree races, especially among the commercial conifers, have been studied for more than 70 years (12).

In the United States the earliest attempts to study races of tree species were made by the Pacific Northwest Forest Experiment Station and the Northern Rocky Mountain Forest Experiment Station in 1915-16. These tests have shown the existence of distinct geographic or climatic races of wide-ranging species such as Douglas-fir (9) and ponderosa pine (15).

Other species that have been under study for a shorter time are lodgepole pine, Englemann spruce, red pine, Scotch pine, and other introduced conifers. Green ash from individual seed trees has been tested prior to use in shelterbelt plantings; and inherently different races have been

found within this species, depending on the locality of seed origin.

In practically all of these studies the seed from local sources--or from similar climatic regions--proved best.

PRESENT STUDY OF RED PINE

The present study to determine racial and individual variation in red pine, and the adaptability of the species to different climatic regions, was begun by the Lake States Forest Experiment Station in 1928. The late Carlos G. Bates (1), who early recognized the importance of seed source in forest management, headed the project.

The Allegheny Forest Experiment Station at Philadelphia and the Northeastern Forest Experiment Station at New Haven (forerunners of the present Northeastern Station) cooperated in the project by collecting seed from several localities in the Northeast.

In 1931 red pines from 37 seed sources were planted at three localities in the Lake States: in the Superior, Chippewa, and Huron National Forests. By 1933 red pine seed had been collected from 144 different sources; stock had been grown, and additional test plantings made at the same three localities.

The 1931 plantings on the Chippewa Forest and all of the Huron plantings failed because of a combination of drought, fire, and other factors. The test plantations have survived at only two localities in the Lake States: in the Superior National Forest in northeastern Minnesota, with 1931 and 1933 plantings; and in the Chippewa National Forest in north-central Minnesota, with 1937 plantings.

Rudolf (10) has reported on the 1931 test plantation in Superior National Forest. This plantation contained seedlings from 37 seed sources, two from New Hampshire, the others from the Lake States. After 16 years it is evident that seed from local northeastern Minnesota sources was best for the site; followed by seed from nearby Minnesota and Wisconsin localities.

THE KANE PLANTATION

As part of this study started by the Lake States Station, a test plantation was established in 1937 at the Allegheny Forest Experiment Station's Kane Experimental Forest in Elk County, Pennsylvania. The purpose of this plantation was to test the adaptability of red pine from various seed sources to conditions on the Allegheny Plateau.

The Seed

Seedlings representing 50 seed sources (table 1) were used in the Kane plantation. These included seed collected in Maine, Massachusetts, New York, and Pennsylvania as well as Lake States seed. Thirteen of the seed sources were the same represented in the 1931 plantings in northeastern Minnesota and reported on by Rudolf (10).

Most of the seed collections were from small groups of trees or limited localities, but 22 (44 percent) were from individual mother trees. The seed trees or groups ranged in age from 30 to 250 or more years, in diameter from 8 to 30 inches d.b.h., in total height from 20 to 102 feet, in clear length from 0 to 55 feet, and in bole form from poor to excellent.

The Site

A 6-acre planting site was selected near the headquarters of the Kane Experimental Forest (fig. 1). This site is a plateau top at an elevation of 2,000 feet above sea level. It slopes slightly to the south and west, an average gradient of 5 percent. The soil is relatively fertile Clymer silt-loam except for the southeast corner, which is poorly drained Cookport silt-loam. This corner was not planted.

The planting site had been cleared and plowed in 1933, using Civilian Conservation Corps labor. Old hemlock stumps were dynamited, and larger stumps of the aspen-pin cherry stand that originally covered the site were pulled with a tractor before plowing. The site was plowed criss-cross.

Figure 1.--The red pine planting site at Kane Experimental Forest at time of planting. Weather station in background.

Planting was originally scheduled for 1934, but white grubs destroyed the nursery stock in the Cass Lake, Minnesota, nursery and it was necessary to sow new lots of seed in the spring of 1934. Since 2-1 transplant stock was desired, it was not available until the spring of 1937. Meanwhile all seedlings and sprouting stumps were grubbed out during the summer of 1935. Blackberry and other vegetation was mowed off and dragged away before planting.

Plantation Arrangement

The plantation area was divided into seven ½-acre blocks. Space was left for a weather station, an area for planting replacement stock, and isolation strips. A row

method of planting was used in all blocks, with 6-foot equilateral spacing.

In six of the seven blocks, 14 trees of each of the 50 seed sources were planted.

The seventh block was divided into two ¼-acre areas. One was fenced to keep out deer, the other to keep out both deer and rabbits. The fencing was used to determine how browsing by deer and rabbits affects pine plantations. In these two half-plots the number of samples had to be reduced to five trees of each seed source. The arrangement in each half-plot was 25 rows, each containing 10 trees—a 5-tree sample of two seed sources.

Row planting has the disadvantage that it fails to produce a stand condition for any one group of seedlings. It also tends to accentuate differences in growth rate, because rows of short trees will be somewhat suppressed, while rows of the tallest trees will have less than the usual competition. So in blocks 1 to 6 the rows were run north and south in an attempt to minimize the shading effect of a tall row over a shorter row. No severe competition occurred during the first 5-year growth period; at 10 years it was just beginning. At this time no trees of any one seed source had been overtopped by adjacent trees.

The big advantage of the row planting in this study was that it permitted a systematic sampling of possible differences in soil conditions from the upper to the lower parts of the plantation site.

The location of each row within each block was random. Seed-source numbers for each row were drawn by lot. The location of the different seed-source trees in each block was recorded and mapped.

Planting & Early Treatment

The "square hole-mound" method of planting--also called the W-method--was used. Holes were dug with mattocks. In each hole the planter formed a wedge-shaped mound of loose dirt in the bottom of the hole and divided the seedling roots so that some fell on each side of the mound. Cylindrical wooden tamps were used to firm the dirt around

Figure 2.--Crew planting 2-1 red pine seedlings in the Kane plantation. This site is inside the deer-proof enclosure.

the seedling. Accurate spacing was accomplished by means of guide strings marked with cloth flags at the proper interval (fig. 2).

Planting was begun on May 6, 1937. It was completed on May 13. During this entire period the weather was cloudy and rainy. A moist spring followed, which gave favorable soil moisture and temperature for early growth.

Browsing deer caused some damage on the unfenced parts of the plantation during the fall and winter; so the entire area was fenced with 8-foot woven-wire stock fence to keep deer out--except one block, which was purposely left unprotected.

Vegetative regrowth of shrubby plants and native tree species was rapid. The red pine seedlings were released from blackberry and other herbaceous and tree growth by mowing back a small circular area around each tree during the second growing season. Sprouts and seedlings of aspen, pin cherry, and maples were mowed back throughout the entire plantation during the third, fifth, and eighth growing seasons.

Mound-building ants killed some red pines that were shading their nests, despite efforts at eradication.

SYSTEMATIC MEASUREMENTS, 1937-47

During the first few years frequent examinations were made to determine causes of initial mortality in the plantation. Early losses were very small--due to careful planting, favorable weather conditions, and possibly to the fencing, mowing, and weeding.

At the 5-year measurement the survivals, by seed-source groups, ranged from 89.3 percent to 95.4 percent (fig. 3). At 10 years (fig. 4) the survivals of the same groups averaged from 79.8 percent to 93.6 percent (tables 2 and 3).

Since differences in survival among seed sources were not significant, average height growth was used as the chief criterion for comparing the seedlings from various seed sources.

Stand Condition In 1947

Ten years after planting, these red pines on the Kane plantation had only recently closed in the rows with their lower branches. Practically all trees in the plantation still had living branches almost to the ground (fig. 5). Natural pruning was just beginning on the lower branches.

Crown-class differences were barely beginning to appear at that time, and all trees had space to grow without overtopping one another. Most trees were straight-boled, although a few had double stems originating near ground

Figure 3.--Part of the Kane plantation 5 years after planting. Note the deer-proof fence and the unprotected block outside the fence at left.

line. The severe glaze storm of February 1950 may affect the future form of some trees; this will be recorded in later measurements.

The youthfulness of the plantation makes it impossible to pick out premium trees or those that are likely to grow to maturity. No outstanding differences among the trees from various seed sources have yet been observed in dendrological characteristics such as length or color of

Figure 4.--The Kane plantation 10 years after planting. This is the same area shown in figure 3. Note the good survival and crown closure. The deer-proof fence has been removed.

needles, branching habit, or bole form.

Plans For Future Measurements

The long-term nature of this study does not require intensive measurements at closer than 5- or 10-year intervals. Checks on mortality were made at frequent intervals in the first 5 years, and measurements of total height and mortality were made at the 5th and 10th years after planting.

Figure 5.--Ten-year growth in the unprotected part of the Kane plantation.

In 1952 and 1957--at 15 and 20 years after planting--measurements of diameter growth and a sampling of heights will be substituted for total-height measurements. The plantation will be thinned to make growing space for the better trees of all seed sources by 1957 at the latest.

ANALYSIS OF 10-YEAR HEIGHT GROWTH

Heights of all surviving trees were measured to 1/10 foot by a 2-man crew, using an extensible measuring pole. This was done in the summer of 1947 and the spring of 1948. From these field measurements, the average total heights of

survivors were computed for each of the seven blocks and each of the 50 seed sources.

Previous analysis of the 5-year height data showed no significant difference due to the block arrangement of the plantation. Therefore the 10-year average heights for the block were combined, and the analysis was based on all living trees of a given seed source in all blocks.

Analysis Of Variance

Applying the analysis-of-variance method to these data shows that seed origin is an important cause of variation in the total heights attained by each of the 50 seed sources studied. Moreover, the grouping of these 50 seed sources into nine geographic-climatic regions brings to light highly significant differences as measured by the value of F (table 4).

In table 4 the variance due to seed source has been broken down further to show the variance due to differences among the nine regions and that due to seed-source variation within regions. The results with regard to variation within region are particularly important in this study. The F value of 1.425 approaches but does not reach significance at the 5-percent level. One may thus deduce that these data support the regional groupings as made, since variation by seed source within regions appears to be random.

This indicates the possibility of distinct racial groupings of red pine based on the geographic-climatic region of seed origin. The performance of seed collected in each region is significantly different from that of other regions, but samples making up the regions are relatively homogeneous within themselves. Only time and additional measurements can show whether differences within regions will continue to be less than differences between regions. It is of interest, however, that both 5- and 10-year growth records show the existence of fairly uniform geographic-climatic races that differ from each other in height growth, though not in morphology. This may be useful as a guide in further studies of red pine.

Seed from those regions at the head of Lake Superior and to the north and west in parts of Wisconsin and Minnesota resulted in significantly poorer height growth in the Kane plantation than did seed from regions south of Lake

Superior in the Upper Peninsula of Michigan, from northeastern and central Wisconsin, and from the north-central portion of the Lower Peninsula of Michigan. In other words, seed from sources geographically closer to the point of planting did better than seed from the western limits of the red pine range.

Differences Between Means

As a follow-up on the analysis of variance, the significance of differences between the means of 10-year height growth of all 50 seed sources was computed by t-test. Despite the relatively narrow range in mean heights, from 8.45 to 11.40 feet, about one-half of the seed sources differed significantly from one or more of the others at the 5-percent level. At the 1-percent level of significance about 17 pairs of seed sources had mean differences that were significant.

Grouping these data into 9 and 12 geographic-climatic regions and testing each possible combination for mean differences confirmed the results of the analysis of variance as to importance of region. Table 6 illustrates the results when 8 Lake States and 4 Northeastern States regions are compared. The underlined mean differences are statistically significant.

RESULTS, WITH SPECIAL REFERENCE TO NORTHEASTERN SEED SOURCES

The seedlings grown from seed from the 50 different seed sources varied greatly in growth response. Seedlings of many of the Lake States seed sources outstripped those from the best Northeastern sources; yet a dozen of the Lake States collections grew more slowly than the seedlings from the Maine seed source--which was the poorest of the Northeastern sources.

Growth Response

When all 50 seed sources were ranked from highest to lowest in growth response, the New York seed ranked 23rd, Pennsylvania 33rd, Massachusetts 35th, and Maine 37th. It is interesting to note that seed from Maine and Massachusetts, the eastern sources most distant from the Kane plantation, made poor growth in comparison with the New York and Pennsylvania seed sources, which are much nearer geographically.

But why did the seed from Tioga County, Pennsylvania, only 70 airline miles from the Kane plantation, fail to produce the best height growth of all?

Certain climatic and biological factors offer an explanation for the relatively slow growth of seedlings from this Pennsylvania seed source. Red pine is not native to those portions of Elk County, western McKean County, or adjacent Forest and Warren Counties that surround the Kane planting site. Nature, over the centuries, has been unable to extend the local Pennsylvania race of red pine into this region because of climate or some other barrier. The red pine from Tioga County is thus not a truly local seed source for the test plantation site.

Differences between the general climates of these two localities are shown in table 5. A much greater variability would doubtless be shown by detailed records of climatic extremes of heat and cold and seasonal distribution of rainfall. Differences in elevation, aspect, slope, tree cover, and other factors, which greatly affect the local climate, are known to exist between these two sites. Some of these climatic factors, as well as soil differences, are likely to influence unfavorably the growth of planted seedlings unless they are from sources that are adapted to similar conditions.

Major Climatic Factors

Climatic data read from state maps, compiled in 1941 by the U. S. Weather Bureau (14), have been used to illustrate the average climatic conditions at specified localities or seed-source regions in the Northeast and Lake States (table 5).

The site of the Kane plantation has a climate typical of a true continental plateau. Winter temperatures are occasionally severe (6). The daily range of temperatures at the open red pine planting site was found to average about 25° F. in summer and 20° F. in winter. Occasional ranges of 45° F. to 52° F. have been recorded. The average annual precipitation for the period 1932-38 was 43.7 inches; as read from climatic maps based on longer term but nonlocal stations this value is 41 inches. The elevation of 2,000 feet above sea level and the radiation of heat on clear still nights tends to make this one of the coolest summer climates in Pennsylvania. Light frosts have been recorded even during the summer months. A record low of -35° F. occurred on the Kane Forest during the winter of 1933-34. The growing season averages 110-120 days and is thus quite short even by Lake States standards.

In comparison with the Kane plantation site, the mother-tree site in Tioga County has a slightly colder winter climate (January average), warmer summer (July average), longer growing season, less summer precipitation, and a considerably lower average annual precipitation. Averages for the various parts of the northern Allegheny Plateau region of northern Pennsylvania and the southern-tier counties of New York show even greater deviation above and below the Kane plantation site averages. This is to be expected, just as the range in climatic conditions for the entire State is wider than that for the Allegheny Plateau alone.

As an exact yardstick of the climatic adaptability of red pine from a given geographic region to another region these data in table 5 leave much to be desired. Regions differing widely in climate can, however, be distinguished. Whether these differences are critical and will affect unfavorably the adaptation of a given species if moved from one region to another cannot be predicted. Use of average climatic data from Weather Bureau stations is not a reliable substitute for test plantings or progeny tests of various tree species.

SEED SOURCES RECOMMENDED FOR NORTHERN ALLEGHENY PLATEAU

Until further tests of red pine from a variety of Northeastern seed sources have been made it would seem advisable to discriminate against seed collected in regions known to be greatly different climatically from the proposed planting sites.

For example, seed from Maine and Massachusetts or even from high elevations in the Adirondack section of New York would seem to be of doubtful value for Allegheny Plateau planting in northern Pennsylvania and southwestern New York. On the other hand, seed from truly local mother-trees in Pennsylvania counties within the natural range of red pine might make better long-term growth than seed of any other source--if used within reasonable altitudinal and north-south limits of the seed-collection site.

But in many places on the Allegheny Plateau truly local red pine seed sources are lacking or inadequate. In such cases it would seem advisable to specify seed from some of the Lake States sources that have proved adaptable and have so far given good survival and height growth in this test plantation.

The recommended priority of Lake States seed-source regions for red pine suitable for use on the northern Allegheny Plateau in northwestern Pennsylvania and western New York are:

1. Central and northeastern Wisconsin.
2. The north-central portion of the Lower Peninsula of Michigan (north and west of Saginaw Bay).
3. The Upper Peninsula of Michigan.

While seed sources from the second region mentioned did best in average height, survival at 10 years was only 89 percent. The central and northeastern Wisconsin sources may thus prove to be the best in the long run.

Seed from the more northerly sources, such as the south shore of Lake Superior and the north shore of Lake Michigan in the Upper Peninsula of Michigan, does not do so

well on the Kane Experimental Forest as that from Wisconsin and Lower Peninsula of Michigan regions. Upper Peninsula of Michigan sources are thus third choice.

By all means--for any planting in Pennsylvania and New York--avoid seed sources from as far north and west as Head of the Lakes, the Brainerd-Cameron area, and all of northeastern and northwestern Minnesota.

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APPENDIX

Tabular Data

Table 1.--Sources of red pine seed tested in Kane plantation, ranked according to average 10-year height growth of seedlings

Collection number	Origin of seed, by seed-source region	Date of collection	Kind of collection[1]	Character of mother tree or trees				
				Form	Age	D.b.h.	Total height	Clear length
					Years	Inches	Feet	Feet
1. Lower Michigan								
29	Higgins Lake State Forest	9/--/27	4	--	Young	--	--	--
54	2.4 miles SW of Rapid River	9/26/28	3	Stunted to fair	35-50	9-12	25-40	--
210	2.7 miles W of Cadillac (Mitchell State Park)	9/27/30	2	Fair	48-52	14-15	42-44	5-12
213	4.6 miles SE of Curran	9/20/30	1	Fair	43	14.3	45	8
2. Central Wisconsin								
60	2 miles W of Kilbourn	9/27/28	3	Stunted	50	9	30	--
61	7 miles W of Tomah	9/29/28	2	Fair	40-42	14	40-45	--
64	8.5 miles NE of Menomonic	9/30/28	1	Fair	38-40	18	35	--
104	5 miles N of Holman (Castle Mound)	9/14/29	2	Stunted	Old	--	4-25	--
108	2 miles NE of Black River Falls	10/5/29	2	Fair	--	--	20-50	--
157	2 miles SW of Eau Claire Hotel	9/16/30	2	Leaning,crooked	100	13.5	51	20
3. Northeastern Wisconsin- Southern Upper Peninsula of Michigan								
10	General vicinity of Trout Lake, Wis.	1927	4	--	--	--	--	--
12	3.1 miles SW of Woodruff, Wis.	5/7/28	1	Excellent	77	15	60	20
16	1 mile S of Schofield, Wis.	5/10/28	2	Short, bushy	45-50	9-11	35-40	--
19	4 miles W of Iron Mountain, Mich.	5/18/28	2	Excellent	75-85	15-18	65-70	--
222	8.2 miles SW of Dykesville, Wis.	10/8/30	1	Fair	56	13.4	45	5
227	8.8 miles N or Irma, Wis.	10/10/30	1	Poor	36	10.7	27	7
230	7.6 miles S of Crystal Falls, Mich.	10/18/30	2	Desirable	235	13.9	63	39
268	Goodman Lumber Co., Pembine, Wis.	9/--/30	3	--	--	--	--	--
298	Vicinity of Trout Lake,.Wis.	11/5/32	4	--	--	--	--	--
295	Commercial seed (NE Wis. & Upper Michigan)	1930-33	4	--	--	--	--	--

(continued)

Table 1.-- (continued)

Collection number	Origin of seed, by seed-source region	Date of collection	Kind of collection[1]	Character of mother tree or trees				
				Form	Age	D.b.h.	Total height	Clear length
					Years	Inches	Feet	Feet
4. New York								
294	Commercial seed	1932	4	--	--	--	--	--
5. Northeastern Minnesota								
35	Van Vee Road near Ely	9/9/28	1	Fine	46	12	50	--
36	0.6 mile W of Aurora	9/11/28	1	Forked	41	13.8	36	15
38	6.6 miles from Virginia	9/13/28	1	Good	45	9	32	12
299	Superior National Forest	1932	4	--	--	--	--	--
6. Brainerd-Cameron (Minnesota & Wisconsin)								
74	Onamia, Minn.	5/27/29	1	Good	38	15	40	--
75	2 miles N of Onamia, Minn.	5/27/29	1	Poor (injured)	30	8	25	--
159	1.7 miles W of Turtle Lake, Wis.	9/19/30	1	Normal	35	9.7	38	12
161	1.5 miles W of Cameron, Wis.	9/20/30	1	Heavy vegetative	52	17.6	45	8
174	6.8 miles N of Brainerd, Minn.	9/24/30	1	Good	170+	24.1	63	25
7. Head of the Lakes (Northern Wisconsin)								
47	6.6 miles S of Iron River, Wis.	9/20/28	1	Fair to good	34	10	30	--
49	5 miles NE of Ashland, Wis.	9/21/28	1	Good	42	13	44	--
165	3.4 miles W of Cedar, Wis.	9/21/30	1	Desirable	105	12.5	57	32
8. Pennsylvania								
267	Tioga County	1931	1	--	--	--	--	--
9. Massachusetts								
123	Winchendon (land of E. Murdock Co.)	9/15/29	3	Good	30-40	--	--	--

(continued)

Table 1.--(continued)

Collection number	Origin of seed, by seed-source region	Date of collection	Kind of collection[1]	Character of mother tree or trees				
				Form	Age	D.b.h.	Total height	Clear length
					Years	Inches	Feet	Feet
10. Northern Upper Peninsula of Michigan								
21	2.5 miles N of ranger headquarters, Lake Superior State Forest, Luce County	5/22/28	3	Rather stunted	80-85	10-18	40-50	--
235	0.6 miles NE of Bessemer	10/14/30	3	Fair	26	8.0	23	4
237	10.0 miles N of Bruces Crossing	10/15/30	1	Desirable	52	13.3	55	25
240	0.8 mile N of Baraga	10/17/30	2	Desirable	122	17.9	55	25
246	10.5 miles W of Munising	10/24/30	1	Poor	39	10.7	25	7
11. Maine								
293	Commercial seed	1932	4	--	--	--	--	--
12. Northwestern Minnesota								
122	Chippewa National Forest	1929	4	Fair to good	Mature	--	--	--
144	0.9 mile S of Jack Smith Cabin, Chippewa National Forest	9/1/30	1	Slender	75	16.6	66	30
178	19.5 miles N of Park Rapids Itasca State Park	9/26/30	2	Desirable	135	18.5	85	55
179	Preacher's Grove, Itasca State Park	9/26/30	2	Desirable	160+	22.3	102	51
181	3 miles W of Bagley	9/27/30	2	Good	63-	14.9	63	12
184	6.5 miles S of Warroad	9/29/30	1	Fair	42	17.7	42	9
188	Plot 50, Twin Lakes, Chippewa National Forest	10/1/30	3	Fair	250+	30.0	90	20
284	West Shore Pike Bay, Chippewa National Forest	9/6/33	1	Good	Old	Large	Large	--
324	Near Douglas Lodge, Itasca State Park	9/2/33	3	Excellent	Mature	18-32	60-85	20-40

[1] 1 = Individual tree.
2 = Small groups.
3 = Limited locality.
4 = General and mixed.

Table 2.--Height growth and survival in Kane plantation, by seed-source region

(Basis: 94 trees of each seed source)

Seed-source region	Seed collection number	Average total height		Survival	
		Fifth year	Tenth year	Fifth year	Tenth year
		Feet	Feet	Percent	Percent
1. Lower Michigan	29	2.40	11.14	90.4	90.4
	54	2.72	11.40	92.6	92.6
	210	2.18	10.09	92.6	90.4
	213	2.33	11.02	85.1	81.9
Regional average	--	2.41	10.91	90.2	88.8
2. Central Wisconsin	60	2.46	11.14	94.7	92.3
	61	2.40	11.33	94.7	93.6
	64	2.20	10.53	96.8	95.7
	104	2.02	9.74	94.7	90.4
	108A	2.25	10.82	95.7	92.6
	157	2.12	10.54	96.8	90.4
Regional average	--	2.24	10.68	95.4	92.6
3. Northeastern Wisconsin--Southern Upper peninsula of Michigan	10	1.93	8.69	91.5	88.3
	12	2.06	10.00	88.3	83.0
	16	2.23	10.22	94.7	92.6
	19	2.25	10.54	97.9	94.7
	222	2.17	10.44	94.7	90.4
	227	2.29	11.13	93.6	89.4
	230	2.04	9.99	96.8	92.6
	268	2.31	10.55	93.6	91.5
	295	2.14	10.15	94.7	94.7
	298	2.03	9.57	94.7	93.6
Regional average	--	2.14	10.13	94.0	91.1
4. New York	294	2.15	10.09	96.8	93.6
5. Northeastern Minnesota	35	2.07	9.50	84.0	81.9
	36	2.20	10.34	95.7	92.6
	38	2.15	9.61	91.5	89.4
	299	2.21	10.17	95.7	95.7
Regional average	--	2.16	9.91	91.8	89.9
6. Brainerd-Cameron	74	2.09	9.93	90.4	87.2
	75	2.30	10.60	90.4	89.4
	159	2.02	9.63	95.7	94.7
	161	1.91	9.39	96.8	89.4
	174	2.09	9.82	93.6	91.5
Regional average	--	2.07	9.87	93.4	90.4
7. Head of the Lakes	47	2.05	10.15	88.3	88.3
	49	2.26	10.47	91.5	90.4
	165	1.79	8.58	94.7	92.6
Regional average	--	2.03	9.73	91.5	90.4
8. Pennsylvania	267	1.94	9.61	91.5	91.5
9. Massachusetts	123	1.93	9.59	93.6	89.4
10. Northern upper peninsula of Michigan	21	2.22	10.46	95.7	94.7
	235	2.25	10.13	96.8	95.7
	237	2.10	9.52	95.7	94.7
	240	1.84	9.08	95.7	94.7
	246	1.76	8.76	89.4	85.1
Regional average	--	2.03	9.59	94.7	93.0
11. Maine	293	1.88	9.54	85.1	79.8
12. Northwestern Minnesota	121	1.86	8.91	89.4	86.2
	144	2.06	9.60	91.5	89.4
	178	2.03	9.52	94.7	92.6
	179	2.10	9.73	96.8	94.7
	181	2.15	9.38	92.6	90.4
	184	1.92	8.45	96.8	92.6
	188	2.04	9.45	90.4	86.2
	284	2.06	9.85	93.6	86.2
	32/	1.88	9.28	87.2	84.0
Regional average	--	2.01	9.35	92.6	89.1

Table 3.--Ranking of seed-source regions according to height growth and survival of seedlings at Kane plantation

Seed-source region	Seed lots	Period since planting	Average total height		Survival		Basis: trees planted in 1937
	Number	Years	Feet	Rank	Percent	Rank	Number
1. Lower Michigan	4	5	2.41	1	90.2	11	376
		10	10.91	1	88.8	11	
2. Central Wisconsin	6	5	2.24	2	95.4	2	564
		10	10.68	2	92.6	3	
3. Northeastern Wisconsin--Southern Upper peninsula of Michigan	10	5	2.14	5	94.0	4	940
		10	10.13	3	91.1	5	
4. New York	1	5	2.15	4	96.8	1	94
		10	10.09	4	93.6	1	
5. Northeastern Minnesota	4	5	2.16	3	91.8	8	376
		10	9.91	5	89.9	8	
6. Brainerd-Cameron	5	5	2.07	6	93.4	6	470
		10	9.87	6	90.4	6	
7. Head of the Lakes	3	5	2.03	7	91.5	10	282
		10	9.73	7	90.4	7	
8. Pennsylvania	1	5	1.94	10	91.5	9	94
		10	9.61	8	91.5	4	
9. Massachusetts	1	5	1.93	11	93.6	5	94
		10	9.59	9	89.4	9	
10. Northern Upper Peninsula of Michigan	5	5	2.03	8	94.7	3	470
		10	9.59	10	93.0	2	
11. Maine	1	5	1.88	12	85.1	12	94
		10	9.54	11	79.8	12	
12. Northwestern Minnesota	9	5	2.01	9	92.6	7	846
		10	9.35	12	89.1	10	

Table 4.--Analysis of variance of 10-year average height measurements for 50 seed sources of red pine

Variance due to--	Degrees of freedom	Sum of squares	Mean square	F[1]
Seed source	49	168.5757	3.4403	2.153
Region[2]	8	75.2484	9.4061	5.886
Within region	41	93.3273	2.2763	1.425
Error or remainder	300	479.3770	1.5979	--
Total	349	647.9527	--	--

[1] Values applying to given degrees of freedom are as follows:

Degrees of freedom	Value of F at-- 0.01	0.05
300 and 49	1.57	1.38
300 and 8	2.55	1.96
300 and 41	1.66	1.44

[2] The regional grouping was the same as that used by Rudolf (10). In this analysis all Northeastern seed sources have been grouped as one region.

Table 5.--Average climatic factors for seed-source regions in the Lake States and Northeastern States[1]

(The Kane plantation site, Tioga County site, and northern Allegheny Plateau are included for comparison with more distant regions.)

Seed-source region	Range in average temperature		Range in average length of growing season	Range in average summer precipitation	Range in average annual precipitation
	January	July			
	°F.	°F.	Days	Inches	Inches
Pennsylvania (entire State)	22-32	66-76	100-200	20-28	34-50
Kane plantation site	24	68	110-120	22	41
Mother-tree site, Tioga County, Pa.	22	69	130	20	34
N. Allegheny Plateau (Pa. & N.Y.)	22-26	66-70	100-140	20-22	32-46
Maine (entire State)	10-24	62-70	120-180	18-24	34-46
Southeastern Maine in red pine range	16-24	64-68	130-180	18-24	34-44
Massachusetts (entire State)	22-30	66-72	140-200	20-26	40-46
Mother-tree site, Winchendon, Mass.	22	70	150-160	22	42
New York (entire State)	16-30	64-74	2/ 90-210	18-28	2/ 28-52
Lake Champlain-Lake George pine region	16-22	64-70	100-150	18-26	28-46
Michigan, Lower Peninsula	18-22	66-70	90-150	16-18	26-30
Michigan, Upper Peninsula	12-16	60-66	80-140	16-20	28-32
Central and northeastern Wisconsin[3]	10-18	66-71	90-150	20-22	28-32
Head of the Lakes (Minn. & Wis.)	10-12	66-68	110-140	19-20	28-30
Brainerd-Cameron (Minn. & Wis.)[4]	4-10	66-70	120-140	18-20	24-30
Northeastern Minnesota	2-14	60-68	100-130	16-20	21-30
Northwestern Minnesota	0- 8	66-68	100-130	16-20	20-26

[1] Read from climatological maps in Climate and Man, U. S. Dept. Agr. Yearbook 1941 (14).

[2] Only the lower Hudson River valley, New York City, and Long Island areas exceed a 180-day growing season. The 52 inches annual precipitation is local on Adirondack peaks.

[3] Also includes southern portion of Upper Peninsula of Michigan of similar climate. Shown as two regions by Rudolf (10).

[4] East-central portion of Minnesota and portion of northwestern Wisconsin adjoining Head of the Lakes region.

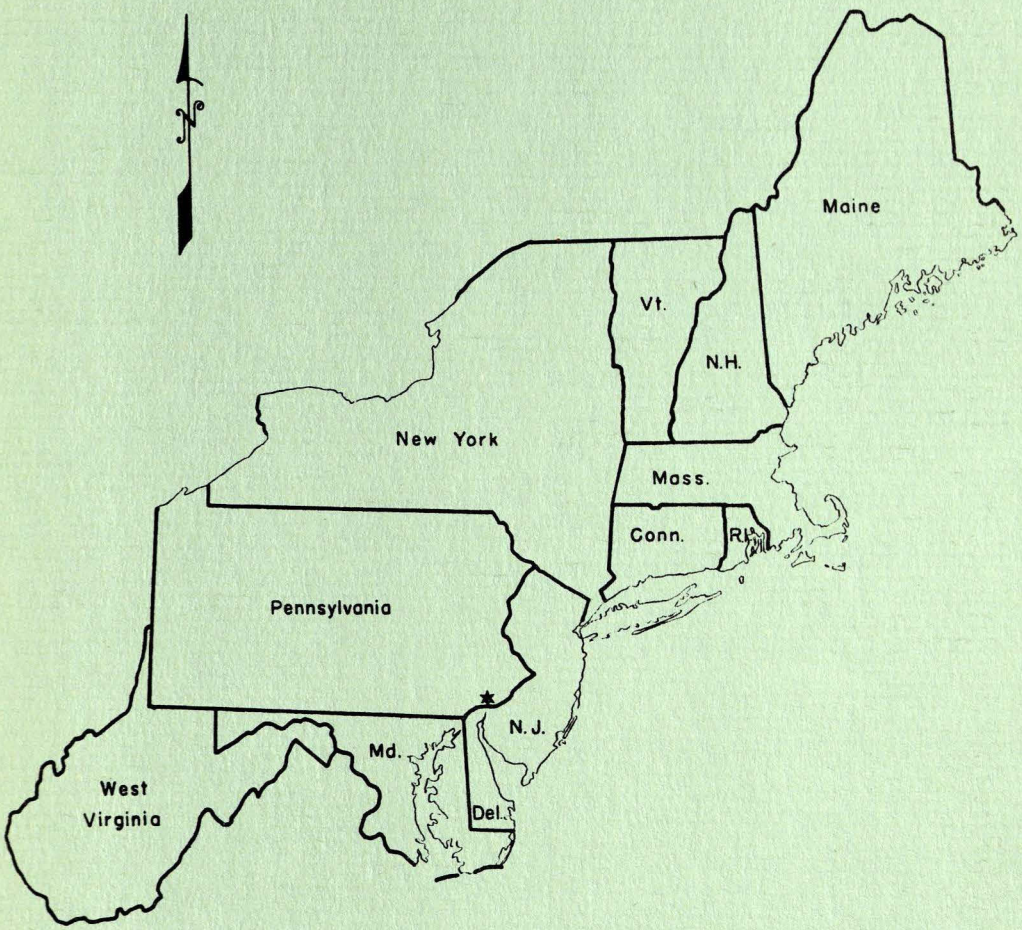
Table 6.--T-test differences between mean heights attained in 10 years by seedlings from Lake States climatic seed sources and seedlings from comparable climatic seed sources in the Northeastern States

Seed-source region and rank	Item[1]	Seed-source region by average height growth of seedlings, and by rank											
		10.91 1	10.68 2	10.13 3	10.09 4	9.91 5	9.87 6	9.73 7	9.61 8	9.59 9	9.59 10	9.54 11	9.35 12
1. Lower Michigan	MD	0	0.23	[2]0.78	0.82	1.00	1.04	1.18	1.30	1.32	1.32	1.37	1.56
	D/F	--	68	96	33	54	61	47	33	33	61	33	89
2. Central Wisconsin	MD	--	--	0.55	0.59	0.77	0.81	0.95	1.07	1.09	1.09	1.14	1.33
	D/F	--	00	110	47	68	75	61	47	47	75	47	103
3. Northeastern Wisconsin and southern Upper Peninsula of Michigan	MD	--	--	--	0.04	0.22	0.26	0.40	0.52	0.54	0.54	0.59	0.78
	D/F	--	--	0	75	96	103	89	75	75	103	75	131
4. New York[3]	MD	--	--	--	0	0.18	0.22	0.36	0.48	0.50	0.50	0.55	0.74
	D/F	--	--	--	--	33	40	26	12	12	40	12	68
5. Northeastern Minnesota	MD	--	--	--	--	--	0.04	0.18	0.30	0.32	0.32	0.37	0.56
	D/F	--	--	--	--	0	61	47	33	33	61	33	89
6. Brainerd-Cameron	MD	--	--	--	--	--	--	0.14	0.26	0.28	0.28	0.33	0.52
	D/F	--	--	--	--	--	0	54	40	40	68	40	96
7. Head of the Lakes	MD	--	--	--	--	--	--	0	0.12	0.14	0.14	0.19	0.38
	D/F	--	--	--	--	--	--	--	26	26	54	26	82
8. Pennsylvania[3]	MD	--	--	--	--	--	--	--	--	0.02	0.02	0.07	0.26
	D/F	--	--	--	--	--	--	--	0	12	40	12	68
9. Massachusetts[3]	MD	--	--	--	--	--	--	--	--	0	0.0	0.05	0.24
	D/F	--	--	--	--	--	--	--	--	--	40	12	68
10. Northern Upper Peninsula of Michigan	MD	--	--	--	--	--	--	--	--	--	--	0.05	0.24
	D/F	--	--	--	--	--	--	--	--	--	0	40	96
11. Maine[3]	MD	--	--	--	--	--	--	--	--	--	--	0	0.19
	D/F	--	--	--	--	--	--	--	--	--	--	--	68
12. Northwestern Minnesota	MD	--	--	--	--	--	--	--	--	--	--	--	--
	D/F	--	--	--	--	--	--	--	--	--	--	--	0

[1] MD = mean difference. D/F = degrees of freedom.

[2] Wavy underline (〰) indicates significant difference at 0.01 level. Straight underline (——) indicates significant difference at 0.5 level.

[3] Very weak sampling in seed source regions of Eastern U. S., and consequent low degrees of freedom for comparisons, making "t" values too low for significance even between better Lake States regions and poorest eastern such as Pa., Mass., and Maine.



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